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OF

The Engineering Society

OF

THE LEHIGH UNIVERSITY.

ISSUED QUARTERLY.

JUNE, 1890.

JOURNAL

OF

THE ENGINEERING SOCIETY.

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ABSTRACT OF PROCEEDINGS.

April 29, 1890. Meeting called to order by Mr. Baily at 19.45 o'clock, with 19 members present. Minutes of last meeting approved. Proposed amendments to constitution read. Prof. Williams read an article on "The Play of a Professional Man," for which he was tendered a vote of thanks. Mr. Baily delivered some remarks on the "Repairs to the Musconetcong Tunnel."

May 20, 1890. Meeting called to order by Mr. Barrett at 19.45 o'clock. Amendments to Constitution [printed below] were unanimously passed. The following officers were elected: *Vice-President*, Mr. Stilson; *Secretary*, Mr. Boatrite; *Treasurer*, Mr. Landis; *Librarian*, Mr. Knapp; *Editors of Journal*, Messrs. Hayes, Escobar, and Barrios. Also *Business Manager*, Mr. Merkle, '84. *Editors*, Mr. Jacoby, '77, Mr. Breckenridge, Ph.B.

FRED. E. FISHER, *Secretary*.

AMENDMENTS TO THE CONSTITUTION.

To I. add "and business manager of the JOURNAL."

To II. add in Sec. 2, "except the business manager of the JOURNAL who shall be an instructor at the University.

III. 1 and 2 remain as at present. 3 shall read, "The duties of the Secretary shall be to record the transactions of the meetings, and attend to all general correspondence." 4 shall read, "The duties of the Treasurer shall be to collect all membership

dues, assessments and subscriptions, keep an itemized account of all receipts and expenditures in a book belonging to the society, and, with the assistance of the Secretary, to attend to the mailing of the JOURNAL." 5 to remain as at present. 6. "The Business Manager shall have charge of the publication of the JOURNAL, shall solicit advertisements, and make collections for the same and shall make all contracts. 7. The Secretary and Business Manager shall keep on file all correspondence relating to their offices."

IV, V, VI not changed.

VII. 2 shall read as follows: "The Board of Editors shall consist of the following, viz.: two instructors, one member of the Senior Class for each school represented in the membership of the Society, and one editor from the Junior Class. The two instructors shall be selected from different engineering schools."

VIII change to: "This Constitution shall not be amended except by a two-thirds (2/3) vote of the members present and voting, the amendment to be submitted to the society in writing at each of two regular meetings before being acted upon."

THE PLAY OF A PROFESSIONAL MAN.

DELIVERED BEFORE THE SOCIETY BY PROF. E. H. WILLIAMS.

We frequently hear the term "gentleman of leisure" used in connection with persons on the other side of the water. It is an honorable title and one to be desired. With us, on the contrary, it is a term of reproach and is attached, principally, to that unsavory horde, the tramps, and sometimes to that ill-favored body known as sharpers, swindlers, gambles, confidence-men, etc. Here, then, are no gentlemen of leisure because there is no such thing known as "leisure" in the best acceptance of the term. We are a set of busybodies. If we have no business of our own we attend to that of our neighbors. We are either ceaseless workers or loafers. It was well said that we lost the art of doing nothing gracefully with the departure of the British dominion. Since that went we have had on our shoulders the fates of the whole world. The American people are noted for nervous energy —haste and impulsiveness: we are no sooner born than we are at work. There are no young men in the business world. Each one has the jaded look of premature age. There is growing up a set of brainless foplings who spend the money earned by their

ancestors in aping the customs of the old world. As far as externals go they may succeed, but when compared with the originals in mental vigor and mental attainments there is no similarity. Beneath the varnish is nothing but base metal. We find no Darwins nor Lubbocks nor Gladstones.

It seemed fit, therefore, as we are a nation of workers, to consider how we pass our time and, to bring the question home to ourselves as individuals, How shall we pass our moments of freedom from work: in other words, how shall we play in the future before us?

If we examine the lives of the workers of an age we shall find that they, too frequently, forget that "All work and no play makes Jack a dull boy," and, too frequently, encroach upon hours that Nature has set aside for relaxation. Nature retaliates for the trespass by a crop of ills that intrude upon the hours for work and cripple the worker. If we turn to the play-time of these men we find it characterized by the same feverishness—there is nothing quiet and healthy about it. It is not relaxation. It is only the same round of the tread-mill under another name. Especially unfortunate is the technical man in this rush through life. With a narrow basis for mental structures he is sent into the world with a limited capacity for enjoyment, and, confined between narrow boundaries, he is furnished with little or no culture and a few tastes of high quality. It seems, therefore, eminently fitting that *we* should consider these questions carefully.

Ever since there arose such a thing as *Education*, there have been differences of opinion regarding its meaning, and how that meaning should best be exemplified. These differences of opinion may be grouped under two heads. The first represents that higher—that highest ideal that would unite culture with education; the other is the "bread and butter" theory that treats man as a machine or as a brute, and would confine him to a tread-mill for life. Unfortunately for you—unfortunately for America—the latter theory has so far prevailed, that all our systems of education are tinctured by it. The great god Mammon demands young victims—as of old—and we yield them without a thought for the result, without a regret at their fate, and think we are doing them a favor when we are sending them into the world as workers before nature has completed their growth, and while their skeletons are cartilagenous and immature.

What wonder if they lay down their tired bodies before the three score and ten years are completed. There is no rest for them but in the arms of our great mother, and to her bosom they hasten for the repose that is denied them here.

When our educational institutions will furnish their alumni with healthful methods of amusements; when public opinion will conclude that our present policy is a selfish one; that our wealth is valuable when it produces good results, and is a curse in every other condition, and that the best man in the community is the one who does best for that community; and that a man cannot do his best till his powers are fully developed and he is fully and completely supplied with means for meeting all emergencies, then—we shall assimilate our courses of study to those of the old world—where we still go for culture, and we shall cease to expect our sons to be fit for life when they have swallowed their dose of learning. If we go to the animals for wisdom, we shall find that even a dog will lie down after his dinner and allow it to digest. Let us go no higher than this brute beast and allow our students to digest and apply what they have learned and let us not be impatient if they be in their twenties when they leave their schools. We shall have a higher class of scholars and their crudities will be worked out in their school-life when no body will be injured.

It is the complaint among technical men that they are not good writers or talkers. A man may have an idea in his head that will benefit mankind, and cannot get it out in such shape as to attract the world. How often are we forced to listen to wretched speeches wretchedly delivered by our foremost engineers! How many bright men have trembled and failed in their after-dinner speeches! Where is the fault? Whose is the fault? If you have had opportunities for exercising your tongue and your pen and have failed to use them you alone are to blame. If the chances have not been made for you by others you share the blame with them. You can begin to-day, however, to secure facility of expression and it will mean dollars to you in the future. But some will say, "There is no time for such things in our course of study." Here we come against the "bread and butter" theory again, which says that a technical man has no more use for tongue and pen than has an animal. But I wish to go farther. I wish to give to you not only facility of tongue and pen, but *tastes* for something beyond and outside of your daily routine of tasks.

If the course does not offer you a chance for the cultivation of such do not sit on the fence and call out, "Why does not the army move?" but remember that you are one of the army, and you can move even if it be stationary. If you move in the right direction you will soon be in the van, where you desire to be. "But," you say, "you are not giving us any play—you are telling us to engage in more work. How will this increase of burden aid us? The bow that is to do good work must be unstrung and rest."

So it must, but you must not confound rest and stagnation. When in the gymnasium you become fatigued by using one piece of apparatus you *rest* by using another that calls into play another set of muscles or which employs the same muscles in an opposite direction. When we unstring the bow to prevent its "setting" we are allowing the elasticity of the fibres to bring it it back to its original curve. The relaxed bow has work to do and does it well. So must you work when you would rest and relax your minds. But *how* shall you rest them? If we take a walk in the woods we shall find, here and there, pools of water. Some are brownish and clear, with wholesome water; some are foul, with crusts and scum on the surface. Both are in repose—the one is the repose of life and we shall find it teeming with minute animals; the other is the repose of putrifaction—another form of life—a low form—the lowest form of life.

Each one of you can recall some pretty sheet of water in some quiet, retired spot. We visit it in summer when the passing clouds and the fringing trees are reflected on its quiet bosom. It conveys to us the idea of rest. We say it is "a bit of still life." We visit the scene in Winter when frozen surface and bordering woods are powdered with snow. We recognize the peace of the scene. It is the repose of Death.

We see, therefore, that rest is a relative term. How are you going to rest in your life, gentlemen? Are you going to secure the rest of life—of work: the rest of putrifaction or rottenness, or the rest of death?

How do you pass your leisure moments as students? The boy is father to the man, and as you bend your twigs as students so your trees will incline as men. Are you aware that you owe a duty to yourself and that you will pay the penalty if you fail in that duty?

Do you come here to study from any desire to better yourselves, or because your parents send you? If the former be your

answer, I have somewhat to say to you; if the latter, you are out of place in this free country of ours, as each American is a sovereign and sovereigns are not sent about at the beck and call of every body. Sopposing that you are all here because you felt that as engineers your life would be successful, I bring this subject before you. Let us consider the question attentively and patiently. I ask your attention because its solution may give you the clue to escape the fate of so many bright men.

> In the world's broad field of battle—
> In the bivouac of life—
> Be not like dumb driven cattle;
> Be a *hero* in the strife—

sings Longfellow, as the true hero is a thinker as well as an actor. If you would show your superiority over the dull clod who has educated his animal nature at the expense of his higher, moral self, and whose limited capabilities compel him, after working with his body at the beck and call of a master mind, to drag back to a home brightened only by the fitful flames of a sensual love that exhausted body, you will so train your minds, now in your youth, and so cultivate your internal resources for recreation, that your return from work, be it what it may, will usher you into a world where the cares and troubles of life cannot intrude; a world that will fit you for the company of the master minds of all ages, when we shall lay down this animal body of ours in the arms of our great mother.

I ask also your patience, as, in the discussion of such a subject, there can be no blare of trumpets; no continued discharge of fire-works; but, as pearls—those emblems of purity—are obtained from the rotting and disgusting heaps of their makers, so step by step we must follow the paths of knowledge through scenes that may not interest us, if we would return well laden.

We allow, therefore, that the age is a busy one, that we go to foreign countries for our thinkers: the greater part of our text-books on abstruse subjects, and the formation of our new sciences. We pride ourselves on being a nation of workers, but we are not a nation of *resters*. We never rest.

When God created the world and its inhabitants he rested on the seventh day and has been resting continually during the myriads of years since that day. We are told continually to enter into His rest because it is *Life* in its highest degree. When time was divided into weeks the seventh day was set apart in com-

memoration of the above fact. Some thought it merely commemorative of a day holier than the other six, and in the reign of anarchy and terror that followed the death of Louis XVI. of France, laws, institutions, and customs were swept away. The reflex wave brought, among wrecks and driftage, a week of ten days: a decimal week: a week that deepened the primeval curse and restricted the time for rest. The law was solemnly exacted; the calendar was changed: the months acquired new names, and God was expunged from the new republic. The result showed that the wise King was terribly correct in saying that true wisdom came from God alone. The new calendar was a failure: the wearied and dying bodies of man and beast rebelled against the unwonted strain, the unnatural strain: and an exhausted nation welcomed back the divine institution. When shall we respect that institution as it deserves?

We are fitted by our Maker for work and rest. We can choose our method in each so long as it is honorable or lawful, and any work is honorable or lawful which is performed in His name. To each of us therefore comes a time when we can pick out our path in life, with the understanding that, once chosen, we must follow it to the end—doing with our might what our brains and hands find to do and looking confidently forward to that final rest that remains for those manly souls who are faithful.

We will all concede that manual labor is not the highest type of work. Laboring men must of necessity form a relatively ignorant class: increasing in ignorance as the work demands bodily rather than mental activity. In the writings of Jesus the son of Sirach, called Ecclesiasticus—the matter is summed more ably than lies in my degenerate pen, and I can do no better than repeat His pregnant words.

"The wisdom of a learned man comes by opportunity of leisure, and he that hath little business shall become wise."

"How can he get wisdom that holdeth the plough, and that glorieth in the goat, that driveth oxen, and is occupied in their labors, and whose talk is of breed of bullocks. He giveth his mind to make furrows; and is diligent to give the kine fodder."

"To every carpenter and work-master, that laboreth night and day; and they that cut and grave seals; and are diligent to make great variety, and give themselves to counterfeit imagery and watch to finish a work:"

"The smith also sitting by the anvil, and considering the iron work, the vapor of the fire wasteth his flesh, and he fighteth with the heat of the furnace; the noise of the hammer and anvil is ever in his ears, and his eyes look still upon the pattern of the thing that he maketh; he setteth his mind to finish his work, and watcheth to polish it perfectly;"

"So doth the potter sitting at his work, and turning the wheel about with his feet, who is always carefully set at his work, and maketh all his work by number; He fashioneth the clay with arm, and tempereth it with his feet: he applieth himself to lead it over; and he is diligent to make clean the furnace;"

"All these trust to their hands; and every one is wise in his work."

"Without these cannot a city be inhabited; and they shall not dwell where they will, nor go up and down;"

"They shall not be sought for in public counsel, nor sit high in the congregation; they shall not sit in the judge's seat, nor understand the sentence of judgment; they cannot declare justice and judgment; and they shall not be found where parables are spoken."

"But they will maintain the state of the world, and all their desire is in the work of their craft."

"But he that giveth his mind to the Law of the Most High, and is occupied with the meditation thereof, and will seek out the *wisdom of all the ancient*, and will be occupied in prophesies."

"He will keep the saying of the renowned men: and where subtile parables are, he will be there also."

"He will seek out the secrets of grave sentences, and be conversant in dark parables."

"He shall serve among great men, and appear before princes; he will travel through strange countries; for he hath tried the good and evil among men."

"Many shall commend his understanding; and so long as the world endureth, it shall not be blotted out; his memorial shall not depart away, and his name shall live from generation to generation."

There is, however, a great exception. Manual labor will not fetter the mind nor will the following of a profession presuppose the possession of wisdom. It is a good old saying that "every tub must stand on its own bottom." In other words, we must judge each case by its surroundings.

Charles Kingsley's Hypatia likens man to a spirit enchanted in a dungeon. We can cultivate our body so as to completely fetter and control the spirit, and we can build and strengthen the dungeon so as to obliterate the spirit. Now and then it may seem to flash for an instant before the grated bars. At times a stifled cry for freedom—for release from the earthly self that crushes it down—may seem to issue from those sombre portals—it is but the ghost of the old self—the echo of an empty name.

Lest I may be thought to have drawn too strong a picture I will refer you to the missionary work in the lowest districts of London, where human beings exist wholly ignorant of such ideas as goodness, purity, morality, and God. As the Bishop of London said, the most that can be done is to teach them to keep themselves clean; their children may be led to a higher plane.

What produced this death in life? Are these guilty of any crime that they be thus debased? Were those upon whom the Tower of Siloam fell more guilty than their neighbors? Certainly not. Such degradation is not climacteric: it is gradual, and its gradations are found in society all the world over. Any man who neglects to exercise a certain muscle will produce more or less total atrophy (as the doctors call it) or death of that muscle. Any man who neglects to use the faculties given him will cause their more or less complete suppression or death. Drummond tells us that death is merely a relative term. A deaf man is dead to noise: noise does not exist—to him. There are neither sun, moon, stars, nor colors, to the blind; no books to the unlettered—no communication with the great minds of the past to the unlearned. Some inherit these peculiarities and should not be held blameable for the sins of their progenitors. I will limit myself to the consideration of those who have talents confided to them and who bury them in a napkin. Let the napkin be ever so costly, such a burial will not free them from responsibility, but a more stern and reproachful voice will strike their ears than that which met Varus returning to give an account of thousands who had perished before the onslaught of our German ancestors, "*Vare! ubi legiones?*" "Varus, what hast thou done with my legions?"

As I stated at the outset, we develop our bread and butter faculties and work them till we drop. "What have we lost?" we cry. "Soul, thou hast acquired much wealth," was the comment in a well known case. We remember the decision, a decision

from which there is no appeal. We see that nothing has been given us fortuitously—nothing has come to us haphazard. Coming to this University we have the chance of learning how to put bread into our mouths—our bread and butter education. The rest of our education must come from our desires for something broader and better. We must educate ourselves. Sitting still will only land us in a net where we can move backward and forward like a horse attached to a gin. We shall be in no way better than the manual laborer. A man does not need a university education to fit him for his place in life. It depends more on the man than the course of study. The right man says that if the way does not exist he will make one for himself.

Elihu Burritt at his Connecticutt forge made wagon tires and horse-shoes with his hands for bread and butter. His mind was not confined within the walls of his dingy smithy, but, with the best minds of antiquity, it wandered at will and drew from them the inspiration that aided him in his efforts to aid mankind. It is his glory that posterity knows him as "The Learned Blacksmith." I could multiply similar cases—of Robert Dide, the baker; of Hugh Millar, the stone-mason, and many others who employed their play-time in work that established science on a firm basis.

"My mind to me a kingdom is," says the poet, and however dark and dreary our prison-house may be, we can leave it on the wings of the imagination and wander at will. Bodily health is not necessary for mental vigor. From a bed of sickness Tom Hood sent forth that series of humorous papers that made his name famous, and amid his own sufferings he felt the woes of others and sang "The Song of the Shirt," while their misfortunes called forth "The Bridge of Sighs," that saddest of records.

The question is now ready to be propounded to each one of you, gentlemen. How are you going to play? How are you going to employ your leisure?

Will you be driven to noise and excitement to distract your thoughts from work? Will your conversation be of balls, and parties, and hunts, and clubs, and, perhaps, of things not mentioned in polite society? Will your home be a place to eat and sleep in—a place to leave for work and for play? Or will you find within yourselves a means of relaxation—a desire for bettering yourself and mankind? Will the light at your fireside not only warm and cheer you, but also attract your friends? Will

you be the ones to draw or to be drawn? There is nothing more dreary than the life of a technical man with no strings to his bow —especially between the end of his college course and the founding of a home of his own. He leaves home and friends and goes, too frequently, beyond the limits of civilization and refinement—without friends or resources. At the end of a dull and tiresome day he foresees only a future of similar long and dreary periods of work and stagnation.

We see that the criticism upon Americans is a just one. We go elsewhere for our thinkers and reasoners. Now and then an Edison, in the moments of relaxation from work as a train-boy or operator, amuses himself by making inventions that revolutionize the world. The idle moments of James Watt produced the steam engine; a pleasure trip of Wedgewood gave to the world the famous ware that bears his name. These are only instances of inventions produced by minds recoiling from the strain of daily tasks.

It is given to very few to possess such an abundance of wealth that they can employ their mental powers to the utmost and engage in whatever schemes may seem to them most attractive. We have seen that such a life of leisure employed in the search for knowledge was the highest type of existance thousands of years ago. In our own time the theories of Charles Darwin—deduced from years of patient research in a life of leisure—have given form and consistence to the beliefs of a large portion of mankind. Weisbach, in his little garden amused himself by experimenting in mechanics and his works are *standards*. There are very few Americans who would be content to live as simply and as frugally as the majority of our great thinkers. The sum of money we possess may not be large in our eyes—but it would enable some deep thinkers in other lands to employ leisure moments to the highest advantage. It remains for us therefore to accept the inevitable law of work and rest—of work to supply our necessities—of rest to raise ourselves and to make the little corner of the world in which we live a little better, and nobler, and purer, for our having lived in it.

One relaxation may be found in books, and we can map out courses of reading at once. When blindness came upon Milton it did not find him with a brain like an attic, stuffed with rubbish, but like a well-arranged library, from which he could reproduce what he had acquired without discord and without error.

How many sick-beds have been enlivened and how many prison-cells lightened by memory. If books do not attract you, there is the world at your feet and around you—a world teeming with life. In the study of that life you may pass many a happy hour. Sir John Lubbock thought it not below his dignity to pass many long weeks and months in the study of a single order of life and his work on wasps, bees, and ants is a classic. He also amused himself in the intervals of Parliamentary sittings in collecting the relics of prehistoric man and has given them to the world so attractively in "Prehistoric Times."

If you have no taste for study in itself, there is the mania so common to humanity of collecting and hoarding, no matter whether the objects be valuable to the world at large or worthless.

There are few boys who have not had their collections of birds' eggs, of postage stamps, of coins, etc., and there are few who have not "outgrown them," as the saying is. Such tastes should be cultivated and the collector should be encouraged to distinguish between valuables and their opposites. There is no truer life than that in the open air studying the wonders of Nature. The naturalist, whether as botanist or geologist, is finding amusement for himself as well as acquiring knowledge of the methods of the Creator. His work will not only convey an ephemeral pleasure to himself, but may add to the stores of learning already acquired by humanity. From such a study one rises with stronger love for his kind—with deeper reverence for his Maker, as—

> He prayeth best who loveth best,
> All things, both great and small :
> For the dear God who made the world—
> He made and loveth all.

Rest and recreation of this sort will end in broadening and deepening our nature and in bringing us closer in contact with our fellows. We can draw from the past lessons of wisdom and warning; we can acquire that true manhood—that high stamp of gentility that places us above the mere accidents of wealth and birth and gives us that symmetrical and rounded training that we call culture, in which the powers of body and mind receive their highest degree of perfection.

From this we see, *lastly*, that knowledge alone is not culture, as a man may be a walking encyclopedia and yet be a boor. We must acquire something beyond learning—something broader and higher than knowledge.

We have thus arrived at the conclusion that our relaxation should be that of the mind rather than the body. We find the mind associated with wisdom, righteousness, and judgment, while to the body are applied the adjectives—earthly, sensual, and devilish. We can make our choice freely; but, if we wish for the best—the highest—the broadest future, let us, like the preacher, choose wisdom. The delights of a life at peace with the world and itself are so truly shown in that poem of an unknown author, whose opening lines I have quoted. Whether he wrote for the Sixteenth Century or to-day, his thoughts should be our thoughts and his choice our choice.

INVESTIGATION OF ECCENTRICITY OF A SEXTANT.

The Pistar and Martin's sextant which is the property of the Sayre Observatory has been in use at this institution for purposes of instruction during 20 years, or thereabout. It does not appear that it has ever been employed for any other work. Although the determinations of latitude and time for which the instrument is mainly used are only for practice it does not seem entirely superflous to investigate its eccentricity, especially as the results obtained from year to year indicate a considerable error from this source.

The correction for eccentricity of an angle measured with the sextant is given by the equation

$$4e'' \sin \tfrac{1}{4}\, n \cos (\tfrac{1}{4}\, n - \alpha) = n - n'$$

in which n = true value of the angle,

n' = measured value of the angle

e'' and α are constants.

For determining these constants the equation is transformed by expanding to the following:

$$(4\, e'' \cos \alpha)(\sin \tfrac{1}{4}\, n \cos \tfrac{1}{4}\, n) + (4\, e'' \sin \alpha) \sin^2 \tfrac{1}{2}\, n = n - n'.$$

Let $x = 4\, e'' \cos \alpha$

$y = 4\, e'' \sin \alpha$

z = any outstanding constant errors

$A = \sin \tfrac{1}{4}\, n \cos \tfrac{1}{4}\, n$

$B = \sin^2 \tfrac{1}{4}\, n$

$N = n - n'$

For a full devolopment of the method employed see Doolittle's practical Astronomy, pp. 196–206.

Then our equation becomes

$$Ax + By + z = N.$$

Measuring a known angle n, the value given by the instrument will be n', then each such measurement will give an equation of the above form for determining x y and z.

In the investigation which follows the angles employed were double altitudes of the sun, 19 such angles were measured, ranging in value from $25^\circ\ 37'$ to $233^\circ\ 50'$, the dates of observation were June 22, 24, 27, and 29, 1889. As some of the measurements on different days were of nearly equal angles some of these were combined, making in all 14 equations.

They are as follows:

1	$.4458x + .7265y + z = -80,$	$p = 1.$
2	$.4591x + .6980y + z = -66,$	1.
3	$.4714x + .6666y + z = -84,$	2.
4	$.4346x + .2528y + z = -48,$	1.75.
5	$.4042x + .2056y + z = -41,$	1.23.
6	$.3866x + .1829y + z = -53,$	1.42.
7	$.3587x + .1516y + z = -25,$	1.
8	$.3247x + .1198y + z = -45,$	1.
9	$.2927x + .0946y + z = -47,$	1.
10	$.2563x + .0707y + z = -56,$	0.7.
11	$.2179x + .0500y + z = -18,$	18.
12	$.1716x + .0304y + z = -24,$	1.
13	$.1361x + .0189y + z = -13,$	0.7.
14	$.1108x + .0124y + z = -15,$	0.7.

Equations 3, 4, 5, and 6 formed by combining two or more series have been assigned greater weight accordingly. While 10, 13, and 14, are given a weight of ½, the last two on account of the difficulty and uncertainty of measurements at such low altitudes, and 10 on account of an uncertainty in the record which, however, did not seem to demand the rejection of the observation altogether.

The following are the resulting normal equations:

$$2.87099x + 2.65439y + 7.12704z = -408.386.$$
$$2.65439x + 3.17082y + 6.04129z = -414.812.$$
$$7.12704x + 6.04129y + 19.06180z = -996.600.$$

From these

$$x = -56''.34 \pm 27''.21.$$
$$y = -61.04 \pm 11.03$$
$$z = -11.87 \pm 7.98.$$

The probable error of a single equation of weight unity is found to be $7''.8$, this value, though not small is not excessise when the method and circumstances of the observations is considered.

From the above values of x and y,

$$4\, e'' = -\, 83''.07,$$

$$\propto = 47^\circ\ 17'.5.$$

The formula for the correction required by this instrument is therefore

$-83''.07 \sin \tfrac{1}{4}\, n \cos (\tfrac{1}{4}\, n - 47^\circ\ 17.'5) - 11''.87 = n - n'$,

from this the following table of corrections has been computed:

Angle.	Correction.	Angle.	Correction.
10°	— 14″.5	100°	— 44″.4
20	— 17 .3	110	— 48 .0
30	— 20 .2	120	— 51 .6
40	— 23 .4	130	— 55 .1
50	— 26 .7	200	— 75 .5
60	— 30 .1	210	— 77 .5
80	— 33 .6	220	— 79 .3
70	— 37 .2	230	— 80 .8
90	— 40 .8	240	— 82 .1
100	— 44 .4		

During the college year 1887–88, six determinations of latitude were made by the method of circumneridian altitudes of the sun. The mean of these values is as follows:

Uncorrected for eccentricity 40° 36′ 6″.3.
Corrected, . . 40 37 24.9.

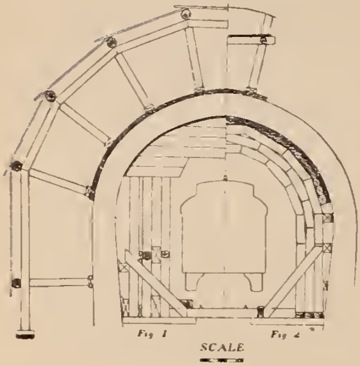
The true value from other sources, 40° 36′ 23″.5.

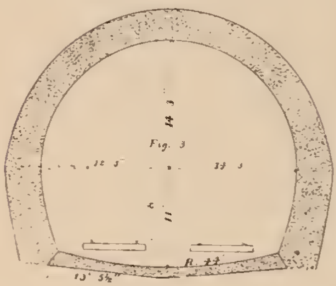
The obsevations from which the above results are derived are not of a very high order of accuracy but they serve as an example of the application of the correction.

REPAIRS TO THE ARCH OF THE MUSCONETCONG TUNNEL.

[Published by permission of the Lehigh Valley Railroad.]

The Musconetcong Tunnel is situated in New Jersey, on the line of the Lehigh Valley Railroad, about twelve miles from Easton. In the Autumn of 1871 and the Winter of 1872 the location was decided upon. The road was at that time divided into four divisions, Mr. Robert H. Sayre, Chief Engineer of the Lehigh Valley Railroad, being also Chief Engineer of the Easton & Amboy Division, in which the tunnel is located. Mr. Calvin





E. Brodhead was Principal Assistant; Mr. John L. Wilson, Division Engineer; Mr. Henry S. Drinker, Resident Engineer, and Mr. Charles McFadden, of Philadelphia, Contractor.

The tunnel is through a spur of the Musconetcong Mountains, that range which extends over Northern New Jersey and into Southern New York, and is 5136 feet long. At the west end it passes through 770 feet of soft ground, 702 feet of which is arched, the remainder being taken out in open cut, 450 feet of limestone, 263 feet of loose rock and 3731 feet of symite, declared by competent judges to be harder and tougher than any rock encountered along the line of the Hoosac Tunnel.

In April, 1872, ground was broken on the west cut, work stating soon after on the east end, and in December, 1874, the headings met. It was decided to commence by a slope down to the level of the proposed headings, which were then to be run in both directions. This was on the west end in the earthy portion of the tunnel, the east end being run full size. The slope having been dug, work was commenced on the headings, but the ground was very heavy, requiring careful timbering. Springs of water were constantly encountered and finally one spring struck with which two large pumps were unable to cope; the water gained rapidly, the timbering was undermined and the entire work ruined. After this the slope was abandoned: a shaft was sunk to the west and headings run each way until the water was struck, when it was carried out through the west heading. This portion of the tunnel was the most troublesome and has kept up its reputation in this respect ever since.*

That portion of the tunnel through the earth and also where

*For further description of the construction of this tunnel see "Tunneling, Explosive Compounds and Rock Drills," by Henry S. Drinker, E.M. New York: John Wiley & Sons. 1882.

the loose rock was encountered at the junction of the limestone and the syenite were arched, there being 50 feet of stone arching at the west end, the remainder of brick. The backing was dry rubble.

For a number of years the brick arch gave good satisfaction, but finally it began to fail. Longitudinal cracks were opened and at last it grew so bad that the bricks would fall out under the jarring of the passing trains. The cause of this failure is not known; the mortar used had not been injured by the water, it was found afterwards. It is probable that the rubble backing was not packed tight enough, thus allowing a pressure from above to be transmitted directly to that portion of the arch below, instead of being distributed uniformly over the entire arch.

Several remedies were suggested and plans made, but first it became necessary to timber the failing part, or there was danger of the entire arch collapsing. The great problem was to put in solid timbering and still not interfere with the trains. The double track was changed to a single one raised on sills and timbering put in as shown in Figs. 1 and 2. The first kind (Fig. 1) was used for 255 feet at the west end, 215 feet of this having knees, and 410 feet of the second kind (Fig. 2). The tunnel starts at station 676+65 and at station 678+20 double timbering was used on account of the character of the arch at that point. The bents are five feet apart, centre to centre, of pine and hemlock, the sills are 8″×12″, the posts 12″×12″, and the corbels 12″×12″. To withstand any lateral pressure the bents are connected by short stints, 12″×12″, hemlock. It will be seen by an inspection of the figures that this timbering is put up in the most substantial manner. The second kind is considered the best, as in it no distortion can take place unless the bents break. This work was commenced in April, 1888.

As for repairing the arch, many plans were suggested. One was to take out the old arch in sections and replace it by a stone arch; another, to take out the old arch as above, replacing it by a concrete one resting upon the old side walls. Neither of these was adopted, but after much deliberation it was decided to excavate above the old arch and back of the old walls and fill in with concrete, removing the old arch after the concrete had set.

In June 1888 the old shaft was opened and a heading run both ways along the crown of the arch. This heading was 6 feet by 6 feet, through very heavy earth and heavy timbering: bull pine

in pieces of from 10 to 12 inches diameter was used and proved very satisfactory; it was much more economical than hemlock, costing less than one third as much per running foot. The bents were put 3 feet apart, centre to centre, allowing a clear space of 5 feet by 5 feet. Above fig. 2 is shown the method of timbering these headings. After being run for about fifty feet the heading was then extended down along the line of the arch to a firm foundation back of the side walls, every other bent being knocked out knocked out for this purpose and replaced by timbering as shown in fig. 1. Along the crown of the arch 6-inch scantling were laid on which the sills, 6 inches by 12 inches rested to support the stubs. Concrete was then put into a thickness of from 4 to 4½ feet on the walls and haunches to 3 feet 6 inches on the crown, thoroughly tamped, and the space above, about 3 feet, tightly packed with dry rubble, the stories being about 1½ feet each way. The concrete was mixed in the following proportions, by bulk:

Alsen's German Portland Cement,	1.
Clean Sand, ...	2¾.
Stone, ...	6¼.

The sand was from Perth Amboy and of a high order, consisting almost entirely of quartz with little or no loam; the stone was that taken from the old tunnel, syenitic gneiss and limestone. This concrete sets thoroughly in four hours.

It was found expedient after the work had progressed to open a new shaft. The old one was 140 feet deep, and 330 feet west, or 150 feet from the end of the tunnel was sunk the new one. From this shaft the headings were run to the ring stones of the tunnel facing. The old shaft was filled with 5 feet of concrete, 14 feet of puddled clay, and the remainder with the material from the tunnel. A Copeland and Bacon (N. Y.) hoisting drum was used.

The concrete invert was put in 30 feet sections on Sundays. The wedges above the corbels being driven out, the bents were jacked up and afterwards put down on 6″ × 12″ blocks. The invert was laid to the arc of a circle of 44 feet radius, 21 inches thick at the extremities, 15 inches at the middle, laid to a form. It was kept clear of water while this work was going on by a Worthington (N. Y. and London) pump; at the same time by levers this water could be thrown up the hill through a 1½ inch pipe to be used in mixing the concrete. This mixing was all

done near the shafts, the concrete being taken down for use in the invert on an inclined railway, a car descending pulled up an empty one. For pumping the water from the backing a Blake (N. Y. and Boston) pump was used. Fig. 3 shows the lines of the concrete arch.

While removing the arch, the air back of the masonry was so foul that an air drum had to be put in. This was a Sturtevant (Boston) drum which is guaranteed to deliver 10,000 cubic feet of air per minute running 600 revolutions. The air was carried along by a wooden box 11½ by 36 inches interior dimensions through the tunnel, snd back of the masonry by branch boxes 10 inches by 12 inches interior. With a pressure of 85 pounds in the boiler this drum made 560 revolutions. Before it was put in, a number of men had been prostrated while working behind the arch.

After the concrete had been in thirty days, the brick arch and sidewalls were taken out; the 50 feet of stone arching being in excellent condition was not touched. The result is a tunnel with many unique features and engineers may well be impatient to impatient to learn how the concrete arch will hold.

Thanks are due to the officers of the Lehigh Valley Railroad for their courtesy to the writer in giving him free access to the tunnel and to the plans. THOS. C. J. BAILY, JR.

THE STRENGTH OF NAILS.

During the last two months Mr. Wallace C. Riddick has been conducting, in the hydraulic laboratory, a series of experiments on the strength of iron nails. The apparatus used for finding the dynamic energy necessary to rupture the nails consisted of a wooden ram weighing 44 pounds and fitting loosely in wooden guides, on one of which was accurately marked a scale of feet and tenths. On a firm support below the weight was placed a heavy joist about two feet in length, to which, with the nail or nails to be tested, was nailed a narrow board in such a manner as to project three or four inches above the joist. Measurements of the height of the top of this board, and of the bottom of the ram, give the fall, from which the amount of work expended in destroying the nail is easily computed. To find the static breaking stresses a lever, consisting of a heavy beam graduated to feet and tenths, was arranged. The nail to be tested was driven through a small piece of board and into the wall. Under this

board the short end of the lever was introduced, while the other end was weighted until the nail was broken. A curious result of these experiments was that, in the case of the smaller nails, their heads were often pulled through the board which they fastened to the wall.

It will be seen from the above that the conditions were as nearly as possible those which would exist in a scaffolding or any temporary structure the safety of which depends, to a great extent, on the nails with which it is put together.

The following tables give the majority of tests made.

Size of Nails.	No. of Nails.	Kind of wood.	Thickness of wood in inches.	No. of tests.	Height of fall in fall.	Foot-pounds.	RESULT.
4-penny.	1	White pine.	7/8	3	.1–.3		Nail pulled out.
“	1	“	7/8	2	.2	8.8	“ sheared.
“	1	Hemlock.	½	2	.5	22	“ “
“	1	“	“	2	.4		“ pulled out.
“	1	Oak.	“	5	.25&above	11	“ sheared.
6-penny.	1	Hemlock.	½	3	.5	22	“ “
“	1	“	“	1	.4		“ pulled out.
“	1	Oak.	“	4	.45	17.6	“ sheared.
“	2	“	“	1	1.4	61.6	“ “
8-penny.	1	Hemlock.	7/8	5	.8	35.8	“ pulled out.
“	1	“	“	2	1.0	44	“ held first fall.
“	1	“	“	6	.4-.7		Nails sheared.
“	2	“	“	4	1.4	61.6	“ “
“	3	“	“	1	2.1	92.4	“ held first fall.
“	3	“	“	2	2.1		“ sheared.
“	4	“	“	2	3.2	141.8	“ almost sheared
“	4	“	“	2	3.1	137.4	Nail sheared.
10-penny.	1	“	1	3	.9	39.6	“ “
“	1	“	“	2&1	.7 & .8		“ held first fall.
“	2	“	“	1	1.5	66	Nails sheared.
“	2	“	“	5	1.5		“ held first fall.
“	3	“	“	5	2.4	105.6	“ sheared.
“	3	“	“	2	2.3		“ held first fall.
“	4	“	“	2	4.	176	“ sheared.
“	4	“	“	1	3.8		“ held first fall.
12-penny.	1	“	1⅛	3	1.6		Nail pulled out.
“	1	Poplar.	7/8	3	1.6	70.4	“ sheared.
“	1	Hemlock and poplar.	1⅛	1	1.4		“ “
“	1	“	“	2	1.3	61.6	“ held first fall.
20-penny.	1	Oak and poplar.	1¼	5	2.1 & 2.2	92.4	“ sheared.
“	1	“	“	1	2.1		“ held first fall.
“	2	“	“	1	3.5	154.	Nails sheared.
“	2	“	“	2	3.4		“ held first fall.

Size of Nails.	No. of Nails.	Kind of wood.	Thickness of wood in inches.	No. of tests.	Breaking Stress.		
					Max.	Min.	Mean.
4-penny.	1	Hemlock.	½	2	238	238	238
"	2	"	"	2	395	379	387
"	3	"	"	2	520	436	478
"	4	"	"	2	754	736	745
"	1	Oak.	"	3	345	306	325
"	2	"	"	2	575	556	565
"	3	"	"	2	740	673	706
8-penny.	1	"	⅞	2	393	360	376
"	2	"	"	2	910	884	897
"	3	"	"	3	1316	954	1081
"	1	Hemlock.	"	3	301	196	246
"	2	"	"	3	650	580	627
"	3	"	"	3	980	901	937
6-penny.	1	Oak.	½	2	500	491	496
"	2	"	"	4	835	665	762
"	1	Hemlock.	"	3	377	266	311
"	2	"	"	2	595	555	575
"	3	"	"	2	918	835	876
10-penny.	1	"	⅞	12	501	302	429
"	2	"	"	12	901	735	825
"	3	"	"	2	1122	1028	1075
"	1	Oak.	"	5	549	405	491
"	2	"	"	2	828	813	820
"	3	"	"	2	1199	1141	1170
12-penny.	1	Hemlock.	1¼	3	392	374	383
"	2	"	"	4	790	620	705
"	1	Oak.	"	2	533	442	487
"	2	"	⅞	2	1090	1046	1068
"	1	"	1⅞	2	570	533	551
20-penny.	1	Hemlock.	1¼	2	772	690	732
"	2	"	"	2	1322	1180	1251
"	1	Oak.	1⅜	2	732	675	703
"	2	"	"	2	1345	1320	1332

We will now endeavor to draw a few practical conclusions. We see that it takes about 35℔. of work, neglecting losses due to impact, to break a tenpenny nail. A man weighing 150℔. and dropping three feet would consequently break in his fall 450÷35 or nearly 13 nails. The danger of subjecting temporary structures to shocks and sudden stresses is apparent. The same nails would bear before breaking over 4000℔. of static pressure.

A more extended series of experiments, not on nails only, but on uniform iron bars, might possibly be made to obtain the relation between the static and dynamic stresses. The work done by the falling ram is $W(h+y)$, in which $W=$ the weight of the ram, $h=$ the height of the fall, and y the fall after impact and before rupture. If the fall is just sufficient to break the piece which is being tested, the energy due to the velocity of the ram at the

moment of rupture will be so small that it may be disregarded. It would seem that the same quantity of work would be required to break the nail whether it be suddenly or slowly applied. Consequently if $W =$ the static pressure and y the distance through which it acts—

$$W(h + y) = W'y$$

If in both experiments the materials have been the same, the crushing of the restraining parts will have been about equal, and we may write $y = y'$. If we can find valves of y which for given materials and conditions are nearly crustant the above equation will give valves of W equivalent to W' and the converse. The data in the tables are insufficient to test the reliability of the formula.

FRED. E. FISHER.

REPORT OF A DUTY TRIAL OF THE BETHLEHEM SOUTH GAS & WATER COMPANY'S PUMPING ENGINE.

BY LESTER P. BRECKENRIDGE, INSTRUCTOR M. E. DEPT., L. U.

The following trial was made with the Senior Class in the M. E. Department as a part of the regular instruction in "Measurement of Power."

THE PLANT.

The pumping station is situated on the south bank of the Lehigh River, about one-third of a mile above the Lehigh Valley Railroad station, South Bethlehem, Pa. The plant consists of two 100 H. P. horizontal tubular boilers; one high duty and one low duty pumping engine, together with the other usual mechanisms necessary for the operating of the same. The water of the river is pumped through a 16″ pipe into either of two reservoirs situated vertically 240 feet above the river and about 700 feet directly up the hillside.

THE BOILERS.

These are of the horizontal tubular type, rated at 100 H. P. each. They are set together in brick-work after the usual manner. There are no peculiar arrangements of setting, either of boilers or grates. They are each provided with two safety valves of the lever type. They are fed by an injector, of which there are two connected to the boilers, one taking water from the hot-well overflow and the other from the force main of the pumps. The draft is regulated by hand with the damper in the pipe leading to the flue above the boilers. They have flush fronts and the

tops of the boilers are covered with ashes level with the brick-work, which extends about four inches above the level of the tops of the boilers themselves.

THE PUMPING ENGINES.

The low duty pump is an ordinary "duplex, high-pressure, direct-acting pump," capable of pumping about 1,000,000 gallons in 24 hours, and is only used in case of accident to the other pump. The high duty pumping engine is a vertical compound-condensing beam and fly-wheel pump. High and low pressure steam cylinders are both steam-jacketed. Jet condenser used, with air pump driven by main engine. Condensing water taken from force main through 3″ Globe valve. Water from hot well taken to tank in boiler-room. Jacket water also taken to same tank in boiler-room. Feed water for boilers taken from tank by injector. Overflow from tank to river.

The cylinder-heads are not jacketed. The cylinders are covered outside with hair felt, over which is placed black-walnut lagging. The connection between the two cylinders is by means of two copper pipes, one at the head end and the other at the crank end of the cylinders.

The governor controls the cut-off of the high-pressure cylinder, but the cut-off in the low-pressure may be varied by hand. The form of governor is the Porter loaded high-speed type.

The valves for the steam distribution are all flat-side valves.

The main valves of both cylinders are driven by eccentrics fixed to the valve shaft, the latter receiving its motion by means of bevel gears from the crank shaft.

The cut-off valves slide on the back of the main valves, are gridiron type, and receive their motion from the valve shaft by cams attached to sleeves whose position on this shaft is regulated by the governor for the high and by hand for the low-pressure cylinder.

The fly-wheel attached to the crank shaft weighs about 8 tons.

METHOD OF CONDUCTING THE TEST.

The test was conducted in accordance with the method recommended by the American Association of Mechanical Engineers.

On the morning of the test the banked fires were started at 4.30 A.M. and the steam was raised to the normal working pressure. The engine was then started and ran until 6 A.M., when it was stopped. At 6.08 A.M. the fire from the furnace of the boiler in use was drawn out and the weighed wood (160lb.) was

placed on the grate. At 6.20 the fire was started under the boiler and the boiler test began with 97℔. steam pressure and the water at a known height in the boiler.

As soon as the steam pressure began to rise the engine was started (9.25 A.M.), the counter having been read and the steam pressure and height of water in the boiler noted. At the close of the test, the water having been fed up 1″ above the starting point, the injector was stopped, and when the water in the glass gauge reached the position it had at the counter was read, also the steam-pressure gauge, which was fortunately the same as it was at the start; and the engine test was declared to be finished (5.50 P.M.) The engine continued to run until the boiler test was brought to a close, a few momnts later.

THE FEED WATER.

The apparatus for weighing the feed water consisted of a tank (24″×38″×30″), a pair of platform scales, and a barrel, into the bottom of which was screwed a 2½″ steam cock.

The scales were leveled on the tank and the barrel was placed on the scales. Water was supplied to the barrel by a hose from above, the water being drawn from a pipe connected with the force main. The temperature of the feed water was thus cold (60°), but the temperature of the hot-well was included in the observations, so that the plant could be credited with its usual temperature of feed. In fact, the thermometer and all apparatus for the test were placed in position the Saturday preceding and observations of temperatures, pressure, and speeds were taken at that time for future use. A rubber suction-hose was attached to the suction-pipe of the injector and the other end carried to the above-mentioned tank. At the beginning and end of the engine and boiler test, the tank was filled to overflowing. Water was weighed in uniform amounts of 350℔. and all the weighing and recording was done by the same person throughout the test.

THE COAL.

The coal was in appearance a good quality of anthracite chestnut. The scales used for weighing the coal were compared with the feed-water scales and there was no essential difference. A box was placed on the scales in front of the furnace and, after balancing it, 500℔. of coal was delivered to the box and the coal used for the test was each time taken from it. The scales were balanced after each firing, so that the difference of these successive readings represented the number of pounds of coal fired each

time. When the box was empty 500lb. more were added and so on to the end of the trial.

STEAM CONDENSED IN THE JACKETS.

In order to weigh the steam condensed in the jackets the pipe which usually conveyed this steam to the tank in the boiler-room was cut and connected with the steam heating coils in the engine-room in order to cool the water as much as possible before weighing it. This water was drawn out by means of a valve placed on the end of a pipe outside the building and connected to the coils.

This water was first drawn into a barrel having a cock in the bottom and this barrel was kept partly filled with water and the condensed steam taken into the bottom of the barrel. The water from the barrel was drawn out into a tub up to a mark corresponding to 120lb. of water at a temperature of 60°. After taking its temperature it was turned out and the amount registered. During the experiment the coils and pipes were kept filled with water up to the middle of the glass gauge on the receiver, directly below the cylinders, provided with the engine for this purpose.

The length of this experiment was 7.5 hours, not as long as the engine test, for the reason that it was necessary to first be sure coils and pipes were full to the middle of the glass gauge.

The results of this test were as follows:

1. Duration of trial, 7.5 hrs.
2. Total weight of water caught in tub (no corrections), 1780lb.
3. Pounds of water condensed in both steam jackets per hour corrected for temperature, 235lb.
4. Temperature of water in barrel, 160°.
5. Proportion which the water condensed in the jackets bears to the total feed water $= \frac{235 \times 100}{1793} = 13.1$

THE DRYNESS OF THE STEAM.

No observations were made during this test to determine the quality of the steam. During two previous trials of the same plant careful calorimetric observations were made which in each case gave less than 1 per cent. of moisture. The steam appeared quite dry and it was so assumed.

INDICATOR DIAGRAMS.

These were taken every half hour. Two Tabor indicators were used on the low-pressure cylinder, two Crosby indicators on the high-pressure cylinder, and a Thompson was used on the pump

chambers. The diagrams from the steam cylinders were quite satisfactory, very regular and indicating perfect freedom of action on the part of the indicators.

Considerable inconvenience attended the obtaining of the cards from the pumps. The light was insufficient and water was dropping from various sources, so that by the time the diagrams were obtained the cards were wet through and had to be dried. It may be that this had some effect on the area of the cards, for it will be noticed that the M. E. P. of the pump cylinders was 5 lb. less than the pressure due to the head between the levels of the water in the pump well and the reservoir.

The correction for spring used in the indicator has not yet been obtained, but it was correct for water pressure within one year.

LEAKAGE OF PUMPS.

The construction of the pumps precluded the determination of leakage by any method of observations made while the pumps were stopped. The writer has therefore given as the leakage 8.8 per cent., which was the amount determined in June, 1888, during a similar trial, in which observations were also made at the south reservoir to determine the number of gallons pumped into the reservoir for a known number of strokes of the pump plungers. The method of determination consisted in making a careful survey and system of measurements of the reservoir and calculating its capacity for each foot of depth. The reservoir is nearly the frustrum of a rectangular pyramid and the calculated capacity is in the opinion of the writer sufficiently exact for a determination of the desired leakage.

MISCELLANEOUS OBSERVATIONS.

Besides the observations to which particular attention has been called, readings were taken in the boiler-room and in the engine-room from the various gauges, thermometers, counters, and so forth, after the usual manner in tests of this nature. All readings were taken at intervals of 20 minutes and each set of readings was taken throughout the test by the same person.

A graphical log was kept of the coal and feed water as a check on the accuracy of the weighing.

RESULTS.

The results of both the engine duty trial and the boiler test are appointed after the method advised by the American Society of Mechanical Engineers. The introduction of a slight change

in the signification of the term duty, whereby the duty of a pumping engine will hereafter mean the number of foot pounds of work performed with 1,000,000 heat units, will be gladly welcomed by every one who is interested in work of this description.

In connection with the report of the boiler test, attention should be called to item 33. It is probable that some error was made in weighing the refuse, which makes this item larger than it should have been. This the writer much regrets, for the boiler was worked for a high economy and all the conditions for such existed during the trial. It is probable that the percentage of refuse was not more than 14 per cent., and if such were the case the evaporation per pound of combustible at and from 212° would be 12.6℔.

METHOD OF CALCULATION.

The following formulæ are those used in connection with the calculations pertaining to the duty trial and are those recommended by the American Society of Mechanical Engineers.

1. $\text{Duty} = \dfrac{\text{Foot pounds of work done}}{\text{Total number of heat-units consumed}} \times 1{,}000{,}000$

$$= \frac{A\,(P \pm p + s) \times L \times N}{H} \times 1{,}000{,}000 \text{ (foot pounds.}$$

2. $\text{Percentage of leakage} = \dfrac{C \times 144}{A \times L \times N} \times 100 \text{ (per cent.).}$

3. Capacity = number of gallons of water discharged in 24 hours

$$= \frac{A \times L \times N \times 7.4805 \times 24}{D \times 144}$$

$$= \frac{A \times L \times N \times 1.24675}{D} \text{ (gallons.)}$$

Percentage of total frictions

$$= \left[\frac{I.H.P. - \dfrac{A\,(P \pm p + s) \times L \times N}{D \times 60 \times 33{,}000}}{I.H.P.} \right] \times 100$$

$$= \left[1 - \frac{A\,(P \pm p + s) \times L \times N}{A_s \times M.E.P. \times L_s \times N_s} \right] \times 100 \text{ (per cent.);}$$

or, in the usual case, where the length of the stroke and number of strokes of the plunger are the same as that of the steam piston, this last formula becomes:

$$\text{Percentage of total friction} = \left[1 - \frac{A(P \pm p + s)}{A_s + M.E.P.} \right] \times 100 \text{ (per c.);}$$

In these formulæ, the letters refer to the following quantities:

A = Area, in square inches, of pump plunger or piston, corrected for area

of piston-rod. (When one rod is used at one end only, the correction is one-half the area of the rod. If there is more than one rod, the correction is multiplied accordingly.)

P = Pressure, in pounds per square inch, corresponding to indication of vacuum gauge on suction main (or pressure gauge, if the suction pipe is under a head.) The indication of the vacuum gauge, in inches of mercury, may be converted into pounds by dividing it by 2.035.

p = Pressure, in pounds per square inch, corresponding to distance between the centres of the two gauges. The computation for this pressure is made by multiplying the distance, expressed in feet, by the weight of one cubic foot of water at the temperature of the pump well, and dividing the product by 144; or by multiplying the distance in feet by the appropriate quantity, found in the following table. The quantities in this table are computed from the weights of one cubic foot of water at the various temperatures, as given by D. K. Clark in his *Rules and Tables*, which also correspond to Charles T. Porter's figures, in his work on the *Richards Steam-Engine Indicator*.

Temperature of Water in Pump Well. Deg. Fahr.	Weight of 1 cu. ft. of Water divided by 144	Temperature of Water in Pump Well. Deg. Fahr.	Weight of 1 cu. ft. of Water divided by 144.
32	.4335	75	.4325
35	.4335	80	.4322
40	.4335	85	.4319
45	.4334	90	.4315
50	.4333	95	.4311
55	.4332	100	.4307
60	.4331	105	.4303
65	.4329	110	.4298
70	.4327		

L = Average length of stroke of pump plunger, in feet.

N = Total number of single strokes of pump plunger made during the trial.

A_s = Area of steam cylinder, in square inches, corrected for area of piston rod. The quantity, $A_s \times M.E.P.$ in an engine having more than one cylinder, is the sum of the various quantities relating to the respective cylinders.

L_s = Average length of stroke of steam piston, in feet.

N_s = Total number of single strokes of steam piston during trial.

$M.EP.$ = Average mean effective pressure, in pounds per square inch, measured from the indicator diagrams taken from the steam cylinder.

$I.H.P.$ = Indicated horse-power developed by the steam cylinder.

C = Total number of cubic feet of water which leaked by the pump plunger during the trial, estimated from the results of the leakage test.

D = Duration of trial, in hours.

H = Total number of heat units ($B.T.U.$) consumed by engine = weight of water supplied to boiler by main feed-pump $\times$ total heat of

main feed-water + weight of water supplied by jacket-pump × total heat of steam of boiler pressure reckoned from temperature of jacket-water + weight of any water supplied × total heat of steam reckoned from its temperature of supply. The total heat of the steam is corrected for the moisture or superheat which the steam may contain. For moisture, the correction is subtracted, and is found by multiplying the latent heat of the steam by the percentage of moisture, and dividing the product by 100. For superheat, the correction is added, and is found by multiplying the number of degrees of superheating (*i.e.*, the excess of the temperature of the steam above the normal temperature of saturated steam) by 0.48. No allowance is made for heat added to the feed-water, which is derived from any source, except the engine or some accessory of the engine. Heat added to the water by the use of a flue heater at the boiler is not to be deducted. Should heat be abstracted from the flue by means of a steam reheater connected with the intermediate receiver of the engine, this heat must be included in the total quantity supplied by the boiler.

DUTY TRIAL OF THE ENGINE.

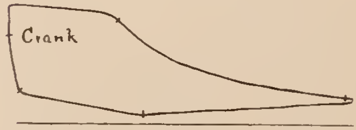
Dimensions.	
1. Number of steam cylinders	2
2. Diameter of steam cylinders, (*a*) High Pressure	13.25″
(*b*) Low Pressure	26.50″
3. Diameter of piston-rods in (*a*) High Pressure cyl.	2.75″
(*b*) Low Pressure cyl.	3.00″
4. Nominal stroke of each steam piston	4.5 ft.
5. Number of water plungers	2
6. Diameter of plungers	15.75″
7. Diameter of piston rods of water cylinders	Are none.
8. Nominal stroke of plungers	2.5 ft.
9. Net area of plungers	194.82 sq. in.
10. (*a*) Area of cross section of H. P. cylinder	137.89 sq. in.
(*b*) " " " H. P. " minus ½ area of rod.	134.92 sq. in.
(*c*) " " " L. P. cylinder	551.55 sq. in.
(*d*) " " " L. P. " minus ½ area of rod.	548.02 sq. in.
11. Average length of stroke of steam pistons during trial	4.5 ft.
12. " " " plungers " "	2.5 ft.
Temperatures.	
13. Temperature of water in pump well	60°
14. " " tank fed to boiler by injector	61°
15. " feed water beyond injector	169.7°
Feed Water.	
16. Weight of water supplied to boiler by injector	20,620lb.
17. " " " " other sources	0
18. Total weight of water supplied to boiler	20,620lb.
Pressures.	
19. Boiler pressure indicated by gauge	99.03lb.
20. Pressure indicated by gauge on force main	91.68lb.
21. Vacuum " " suction main	No gauge.
22. Pressure corresponding to vacuum given in preceding line	———
23. Vertical distance from gauge on force main to water in pump well	28.13 ft.
24. Pressure equivalent to vertical distance in preceding line	12.18lb.
Miscellaneous Data.	
25. Duration of trial	11.42 hr.

26. Total number of single strokes of both plungers during trial..	41,494
27. Quality of steam supplied to engine........	Dry.
28. Total leakage of pumps, determined from results of leakage test........	92,338 gal.
29. Mean effective pressures (*a*) Head end H. P. cylinder........	41.84lb.
(*b*) Crank end H. P. "	43.91lb.
(*c*) Head end H. P. "	11.93lb.
(*d*) Crank end H. P. "	12.16lb.
Principal Results.	
30. Duty........	88,011,000.
31. Percentage of leakage........	8.8 per cent.
32. Capacity for 24 hours........	2,206,300 gal.
33. Percentage of total frictions........	9.26 per eent.
Additional Results.	
34. Number of double strokes of each steam piston per minute....	30.29
35. Indicated H. P. developed by (*a*) H. P. cylinder........	47.78
(*b*) L. P. "	54.55
(*c*) Both. "	102.33
36. Feed water consumed by plant per hour..	1793lb.
37. " " " per I. H. P. per hour corrected for moisture in steam........	17.52lb.
38. Number of heat units consumed per I. H. P. per hour........	20,263.6 B. T. U.
39. " " " I. H. P. per minute......	337.7 B. T. U.
40. Steam accaunted for by the indicator diagrams—	
(*a*) At cut-off in H. P. cylinder, lbs. per hour........	1111
(*b*) At release in H. P. " " "	1354
(*c*) At cut-off in L. P. " " "	1354
(*d*) At release in L. P. " " "	1388
41. Proportion which steam accounted for by the indicator bears to the feed water, minus water condensed in the jacket—	
(*a*) At cut-off in H. P. cylinder........	71.33 per cent.
(*b*) At release in H. P. cylinder........	86.92 per cent.
(*c*) At cut-off in L. P. cylinder........	86.92 per cent.
(*d*) At release in L. P. cylinder........	88.60 per cent.

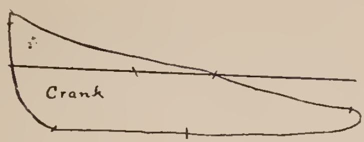
SAMPLE DIAGRAMS—FROM STEAM CYLINDERS.

H. P. cyl. 13.25″ diam. L. P. cyl. 26.5″ diam. Stroke 54″.

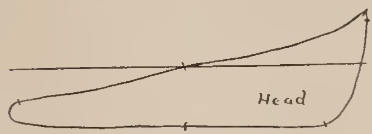
Scale 80. R. P. M. 31. M. E. P. 44.30. H. P. cyl.



Scale 80. R. P. M. 31. M. E. P. 42.50. H. P. cyl.



Scale 20. R. P. M. 31. M. E. P. 12.03. L. P. cyl.



Scale 20. R. M. P. 31. M. E. P. 11.90. L. P. cyl.

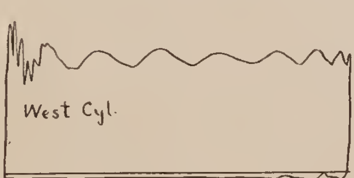
MEASUREMENTS FROM STEAM CYLINDER DIAGRAMS.

[Refer to marked points on diagrams given.]

	H. P. cyl.	L. P. cyl.
Initial cylinder pressure above atmosphere	95lb.	11.5lb.
Pressure at cut-off " "	85lb.	0lb.
Release pressure in cylinder above zero	36.6lb.	8.12lb.
Back pressure at mid-stroke " "	40.7lb.	2.12lb.
Pressure at which compression begins above zero	36.6lb.	2.12lb.
" " " ends " "	69.6lb.	23.62lb.
Proportion of stroke completed at cut-off, head end	.30	.51
" " " " crank end	.32	.58
" " " release head end	.97	.975
" " " " crank end	.98	.965
Steam accounted for per hour per 1 H. P. at cut-off	10.84	13.19
" " " " release	13.19	13.48
42. Number of double strokes of plungers per minute		30.29
43. M. E. P. measured from pump diagrams		97.85lb.
44. I. H. P. developed in pump cylinders		87.52

Diameter of plungers 15.75″ Stroke 30″

Scale 80. R. M. P. 31. M. E. P. 97.90. Stroke 2.5ft. Diam. 15.75″.



Scale 30. R. P. M. 31. M. E. P. 98.79. Stroke 2.5ft. Diam. 15.75″.

RESULTS OF THE TRIAL OF A HORIZONTAL TUBULAR BOILER AT PUMPING STATION, SOUTH BETHLEHEM WATER WORKS, TO DETERMINE ITS EVAPORATIVE EFFICIENCY IN CONNECTION WITH A DUTY TRIAL.

ITEMS.	
1. Date of trial	May 19, 1890.
2. Duration of trial ....11 hr. 32 min.	11.503 hr.
DIMENSIONS AND PROPORTIONS.	
Description of Boilers.	
(*a*) Type of boiler	Horizontal tubular
(*b*) Diameter of shell	66″
(*c*) Length of shell	16 ft. 6″
(*d*) Number of tubes { Vertical	—–
(*d*) Number of tubes { Horizontal	107
(*e*) Diameter of tubes	3″
(*f*) Length of tubes { Vertical	—
(*f*) Length of tubes { Horizontal	16 ft. 2″
(*g*) Diameter of steam drum	24″
(*h*) Length of furnace	6 ft.
(*i*) Width of furnace	5 ft.
(*j*) Kind of grate bars	{ Plain stationary cast iron.
(*k*) With of air spaces	7-16″
(*l*) Ratio of area of grate to area of air spaces	1 to .31
(*m*) Area of chimney	11.75 sq. ft.
(*n*) Height of chimney above grate	70 ft.
(*o*) Length of flues connecting to chimney	14 ft.
(*p*) Area of flues eonneeting to chimney	7.06 sq. ft.
Governing Proportions.	
(*a′*) Grate surface	30 sq. ft.
(*b′*) Heating surface { Water	1438 sq. ft.
(*b′*) Heating surface { Steam	None.
(*b′*) Heating surface { Total	1438 sq. ft.
(*c′*) Area of draught through or between tubes	4.54 sq. ft.
(*d′*) Ratio of grate to heating surface	1 to 47.91
(*e′*) Ratio of least draft area to grate	1 to 6.6
(*f′*) Ratio of least draft area to total heating surface	1 to 316.6
(*g′*) Water space. (cu. ft.)	
(*h′*) Steam space. (eu. ft.)	
(*i′*) Ratio grate to water surface	
(*j′*) Ratio grate to steam spaee	
3. Grate surface, wide 5′ long 6′ area	30 sq. ft.
4. Water heating surface	1438 sq. ft.
5. Superheating surface	None.
6. Ratio of water heating surfaee to grate surfaee	47.91 to 1
Average Pressures.	
7. Steam pressure in boiler by gauge	99.03lb.
8. Absolute steam pressure	113.65lb.
9. Atmospheric pressure per barometer	14.62lb.
10. Force of draft in inches of water	0.2 in.
Average Temperatures, Fahr.	
11. Temperature of external air	70°
12. Temperature of fire room	75°
13. Temperature of steam	337°
14. Temperature of escaping gases	330°
15. Temperature of feed water	61°
Fuel.	
15½. Cost of coal per 2000lb. at boilers	
16. Total amount eoal consumed (includes wood 160lb. x 0.4)	2300lb.
17. Moisture in eoal, 1 per cent	23lb.
18. Dry coal consumed	2277lb.
19. Total refuse dry, 439 pounds	19.28 per cent.
20. Total combustible (item 18 less item 18)	1838lb.

21. Dry coal consumed per hour	197.1lb.
22. Combustible consumed per hour	159.9lb.
Results of Calorimetric Tests.	
23. Quality of steam (dry steam taken as unity)	1
24. Percentage of moisture in steam	0
25. Number of degrees superheated	0
Water.	
26. Total weight of water pumped into boiler and apparently evaporated	20,620lb.
27. Water actually evaporated corrected for quality of steam	20,620lb.
28. Equivalent water evaporated into dry steam from and at 212° F	24,682lb.
29. Equivalent total heat derived from fuel in British thermal units	23,835,407 B. T. U.
30. Equivalent water evaporated into dry steam from and at 212° F. per hour	2146lb.
Economic Evaporation.	
31. Water actually evaporated per pound of dry coal from actual pressure and temperature	9.05lb.
31½. Equivalent water evaporated for $1.00 from and at 212° F.	
32. Equivalent water evaporated per pound of dry coal from and at 212° F.	10.83lb.
33. Equivalent water evaporated per pound of combustible from and at 212° F	13 43lb.
Commercial Evaporation.	
34. Equivalent water evaporated per pound of dry coal with one-sixth refuse at 70 pounds gauge pressure from temperature of 100° F. (= item 33 x 0.7249)	9.66lb.
Rate of Combustion.	
35. Dry coal actually burned per square foot of grate surface per hour	5.72lb.
36. 191.9 { Consumption of dry coal per hour, coal assumed with one-sixth refuse. } Per sq. ft. of grate surface	6.40lb.
37. Per sq. ft. water heat'g surf.	0.133lb.
38. Per sq. ft. least area draught	42.22lb.
Rate of Evaporation.	
39. Water evaporated from and at 212° F. per square foot of heating surface per hour	1.49lb.
40. 18.67 { Water evap. per hr. from tem. of 100° F. into steam of 70 pds. gauge pressure. } Per sq. ft. of grate surface	62.2lb.
41. Per sq. ft. water heat'g sur.	1.30lb.
43. Per sq. ft. least area dr'ght.	410.7lb.
Commercial Horsepower.	
43. On a basis of 30 pounds water per hour evaporated from a temperature of 100° F. into steam of 70 pounds gauge pressure (= 34½ pounds from and at 212° F.)	62.2
43½. Number of horsepower obtained for $1.	
44. Horsepower, builders' rating at 15 square feet per H. P.	96.
45. Per cent. developed below rating	35.1
Remarks.	
46. Cost of dry coal for 1 H. P. for 24 hours	
47. B. T. U. derived from 1 pound of coal	10,464

The writer desires to express, in connection with this report his thanks to Mr. Lehman, as Superintendent of the Water Company for his courtesies in connection with the test and also to acknowledge his indebtedness to Mr. Farrell the engineer at the pumping station, for much valuable aid in preparation for the trial as well as for his endeavors to make it a success.

L. P. BRECKENRIDGE.

ALUMNI NOTES.

1883.

—Chas. L. Rogers, M. E., is General Manager, Milton Car Works, Milton, Pa.

—Francis W. Dalrymple, C.E., has resigned his position as roadmaster of the Bradford Division, New York, Lake Erie & Western R.R., and became City Engineer of Bradford, Pa.

1884.

—G. H. Nelson, C. E., is in the Pennsylvania Railroad's employ at Altoonah, Pa.

1889.

—John T. Morrow, M.E., is with the United Edison Manufacturing Company, offices 165 Fifth Avenue, New York City.

1890.

—Thos. C. J. Baily, Jr., C.E., is in the office of the Assistant Engineer, Erie and Ashtabula Division, Pennsylvania R.R., New Castle, Pa.

—John W. DeMoyer, C.E., has accepted a position on an engineering corps on the Camden & Atlantic Railroad, with headquarters at Camden, N.J.

—Frank R. Fisher, C. E., is with the Bristol Land Company. Address, care of Geo. N. Beel, Bristol, Tenn.

—Ralph Goodman, C.E., has obtained a position as transit man on the Philadelphia & Reading R. R. His address is P. & R. R.R., Ninth and Green Sts., Philadelphia, Pa.

—Henry M. Kurtz, C. E., is with the Susquehanna Coal Company, Wilkes Barre, Pa,

—Edwin J. Prindle, M.E., having finished his University work, has returned to his home in Washington, where he will study law preparatory to entering the bar as a patent lawyer.

—Wm. A. Stevenson, M.E.. has obtained a position with a large manufacturing company at Erie, Pa.

—A. H. Van Cleve is with the King's County Elevated R.R., Brooklyn, New York.

EDITORIALS.

Our Volume is closed, we have done our part as well as was in our power, and if aught is wanting, as there undoubtedly is, we beg our friends to overlook it; for of however small account these few contributions, wrung with toil and trouble from an apathetic society may seem, they have cost us much. It has always appeared pitiful to us that the Engineering Society should be so ill supported. Whether it is because the technical work of our courses requires a relaxation from all such subjects, during our limited spare hours, or whether it is only laziness inherent in "the beast," is an open question. Nevertheless it is a fact, that during the last year we have slumbered like a Florida alligator in his swamp, only to wake for one or two fitful moments, when a seemingly palatable morsel was temptingly displayed.

We hope that our successors will not have the same difficulty to contend with, for when looked at closely, our Journal is not an altogether discreditable exponent of our University. It finds its way into every portion of our land, and to some points beyond; it is a tangible witness that here are being prepared men for the world's work, and well prepared. To our professors and instructors who have given us willing aid, we extend our thanks.

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